The Environmental Tax versus Tariff Revenue Financed Environmental Protections

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I. Introduction

Now that environmental pollution matters are widely acknowledged around the world and corresponding to this phenomenon, the nations of which include some LDCs have come to explore environmental protection strategies. As regard to environmental policies, it is commonly known that the market based environmental protection methods [i.e., pollution taxes, pollution permits, etc] are prevalent in textbooks of the environmental economics and accordingly, they are said to be effective so as to target pollution directly. However, introducing and practicing of those methods in certain developing nations have some bottlenecks since those market based environmental policies are strongly based on the "ppp", the polluter pays principle and it is difficult to be worked in certain developing nations due to a lack of appropriate institutions[1] for pollution monitorings. In this respect, we would be forced to abandon to introduce such first best policies whose purposes are to target distortions directly.

Turning to the second best aspect of the environmental protections, observing trade and the environmental linkages, one might notice that free trade policy could be a vehicle for environmental protections. It derives from the formal analysis demonstrated by Copeland (1994). Accordingly, if the trade protected sectors are pollution damage intensive, then removing trade barriers would serve a reduction in outputs of those sectors and thereby pollution. It implies that a reduction in trade barriers not only reduce domestic distortions attached with trade barriers, but also reduces the environmental pollution. At this point, despite the fact that trade policies are not the first best policies for environmental protections, they would be potential

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environmental policy tools.

However, the situations in developing nations could not permit them to implement free trade policy due to the existence of trade protectionisms arising from various political reasons or else. Among them, one of the seemingly plausible justifications of trade protection is that trade protection can be a source of domestic revenue. Consider for example, for the case of tariffs protection, the revenue generating from tariffs should not be a ignorable one due to the fact that it can sustain[2] most part of domestic revenue in LDCs. Hence, a reduction in tariffs implies a reduction in domestic revenue. Furthermore, if tariffs revenue is earmarked for the public good provision, and suppose that initial public good provision is a sufficiently below at socially optimal level, a reduction in tariffs leads to welfare reducing, demonstrated by Abe (1992).

Considering those bottlenecks of environmental protections, one of the purposes of this paper is to explore an alternative environmental protection scheme when the noted shown above market based environmental policy tools are difficult to be forced. That scheme would be the tariff revenue financed environmental protection, whose another name in this paper is the tariff revenue financed public abatement. At this point, the mechanism of public abatement in this paper is so simple that government in the economy implements environmental protections by using tariff revenue in lie of imposing the market based environmental policies on private sectors. In theoretical literatures, public abatement has been analyzed by many authors since the publication of Khan (1995). For example, Chao and Yu (1999) introduced the public abatement financed by both environmental tax revenue and an international aid and analyzed the effect of aid in a two country's framework. Subsequently, Hatzipanayotou, Michael and Lahiri (2002, 2003) introduced trans-boundary pollution and demonstrated the effect of an international aid and the environmental tax on public abatement and welfare in a small open economy's framework. Bovenberg and Ploeg (1994) dealt with the employment effect in public abatement framework in a different model from the above literatures.

Reflecting upon those past contributions, one might acknowledge the importance and the effectiveness of public abatement, which is financed by the environmental tax revenue and an international aid, yet one should be noted that there have been ignored other domestic taxes just like a tariff, consumption tax, etc to finance public abatement. In case of developing nations where the environmental tax is difficult to be introduced and tariff revenue is a main source of domestic revenue, the tariff revenue financed public abatement could be the environmental policy. Regarding to this, the one of the main results of this paper in which the tariff revenue financed public abatement can increase domestic welfare and tariff revenue via a reduction in pollution without removing a tariff, would be highly appreciated. This is because it enables the tariff based protection oriented countries to protect the environment without sacrificing their domestic revenue.

Another novelty of this paper is that the author addresses both the environmental tax and a tariff imposition simultaneously in order to compare which tax revenue should be earmarked for public abatement[3] so as to increase domestic revenue and welfare effectively. This analysis is somewhat worthwhile in the sense that government can make a decision as to how and which tax revenue should be earmarked for public abatement or lump sum distributed to households. In this respect, we know the situation that there exist the countries where the environmental tax is introduced and its revenue is earmarked for public abatement, and therefore introducing the environmental tax into the current tax structure enables us to consider fiscal matters[4] and so it should be also worth exploring.

The layout of this paper is as follows. Section 2 introduces a trade theoretical general equilibrium model. Then, the first parts of section 3, we introduce the environmental tax and a tariff independently so as to illuminate a clear distinction about the welfare consequences of these taxes' revenue financed public abatement. The remaining parts of Section 3, we impose both taxes simultaneously and examine whether both taxes revenue should be earmarked for public abatement or not, to enhance revenue and welfare. Section 4 concludes this paper.

Ⅱ. The Basic Model

The economy is assumed to be a perfectly competitive and small open. And there produce two private internationally traded goods; the imported good and the exported good, and therefore their prices are fixed under the small open economy's assumption.

There generates only one type of the environmental pollution, which is a by-product pollution in such a way that the production of the imported good generates pollution. To reduce pollution, the economy provides public abatement g from a central agency without any charges, and we assume $g \leq z$.

The factors of production are also perfectly competitive and internationally immobile. The production function is homogeneous of degree one and is concave in all factors.

The full employment of factor condition can be expressed as follows.

$$v^p + v^g = v$$

where v denotes total endowment vector and v^p are the amount of factors used in the production of the private goods while v^g are that of used in supply of public abatement.

Let us define the relative price of the imported good as p while the price of the exported good is numeraire. At this point, if the economy imposes a specific tariff whose rate is s, then a difference of internationally relative price of the imported good p* and the domestic relative price of the imported good p equals to s $(p = p^* + s)$.

The production side of the economy can be characterized by the following revenue function whose purpose is to maximize private goods production.

$$\tilde{R}(p, v^p) = \max_{x,y,z}\{px + y : (y, x) \in T(v^p)\}$$

where x denotes the output of the imported good, while y denotes that of the exported good, and T (v^p) indicates the technology of producing the private goods in the economy. Besides, one should recall the fact that the economy provides public abatement to reduce pollution. Thus, to incorporate public abatement into the revenue function, we demonstrate a little manipulation to yield the following relationship $\tilde{R}(p, v^p) = R(p, g)$[5] where g denotes a provision of public abatement. And it is generally known that partially differentiating the revenue function with respect to the price yields the output, $R_p \equiv \partial R/\partial p = x$ and the revenue function is a strictly convex in the price as $R_{pp} > 0$. Furthermore, $-R_g > 0$ can be defined as the unit cost of public abatement and so the total cost of public abatement is $-gR_g > 0$. And we assume $-R_{gg} = 0$.

Since the imported good production generates pollution and taking account of this; we establish the following equation.

$$z = \Pi(R_p(p, g)) \quad (1)$$

where z indicates the amount of pollution generating from the imported good production.

Although we have ignored the environmental tax so far, when the economy imposes the environmental tax on the private sector, then revenue function can be redefined as,

$$\tilde{R}(p, t, v^p) = \max_{x,y,z}\{px + y - tz : (y, x) \in T(v^p)\}$$

where t indicates the environmental tax rate. By using the envelop theorem, one can derive the following pollution equation which corresponds to (1).

$$z = -R_t(p, g, t) \quad (1)'$$

Turning to the consumption side, let us define the utility function as $u = \Phi(C_x, C_y) + \Psi(z-g)$[6], where C_x is the demand for the imported good x while C_y is that of the exported good. Note that the environmental pollution harms utility and so we assume $\Psi'(\cdot) < 0$. The economy has a representative consumer with the following expenditure function.

$$E(p, z-g, u) = \min_{C_x, C_y}\{pC_x + C_y : u \leq U(C_x, C_y, z, g)\}$$

Since pollution causes a negative impact on utility, expenditure should be increased as $E_z > 0$, which is commonly known as the marginal willingness to pay for a reduction in pollution, to keep utility level constant. From the property of the expenditure function, we know that $E_u > 0$[7] is the reciprocal of the marginal utility of income and $E_p \equiv \partial E/\partial p = C_x$ is the compensated demand for the imported good and second derivative of the expenditure function is negative as $E_{pp} < 0$.

And it is the nature of public abatement that the public abatement fund is financed by tax revenue in such a way that a certain fraction of tax revenue is earmarked for public abatement, while the remaining fraction of tax revenue is distributed to households. With this in mind, the following equation can describe the economy's budget constraint.

$$E(p, z-g, u) = R(p, g, t) - gR_g(p, g, t) - (1-\alpha)tR_t(p, g, t) + (1-\beta)sM_p(p, z, g, u) \quad (2)$$

The first term of the RHS of (2) indicates the revenue from the private good production. The second term of the RHS indicates the factor income from public abatement. The remaining terms are domestic taxe revenues whose fractions of α, β are earmarked for public abatement while the remaining fractions, $(1-\alpha), (1-\beta)$ are distributed to households. At this point $-tR_t(=tz)$, sM_p are the environmental tax revenue and tariff revenue respectively where $M_p = E_p - R_{p>0}$ indicates imports.

Under the assumption that a fraction of taxes' revenue is earmarked for public abatement; then one can establish the following government's budget constraint for public abatement.

$$-gR_g(p, g) = -\alpha tR_t(p, g, t) + \beta sM_p(p, z, g, u) \quad (3)$$

Combining (2) with (3), one can simplify the economy's budget constraint.

$$E(p, z-g, u) = R(p, g) - tR_t(p, g, t) + sM_p(p, z, g, u) \quad (4)$$

There are three equations (1), (3), (4) accompanied with three endogenous variables z, g, u. The exogenous policy variables are a fraction of taxes' revenue α, β[8] for public abatement. Totally differentiating equation (1) or (1)' and (3), (4), then one obtain the changes in public abatement, pollution and welfare.

Ⅲ. Tax Revenue Financed Public Abatement and Welfare

In this section we wish to examine the changes in the endogenous variables by varying the exogenous policy variables α, β.

The Environmental Tax revenue Financed Public Abatement without Tariff Imposition

Firstly, let us assume that the economy imposes only the environmental tax to finance for public abatement. In this circumstance, totally differentiating (1)', (3), (4) with $\beta = s' = 0$, $d\beta = 0$ yields the changes in endogenous variables. One can derive them by using comparative statics (see appendix A).

$$dg/d\alpha = tR_t/\Theta \tag{5}$$

$$dz/d\alpha = -R_{tg}(dg/d\alpha) = -tR_{tg}R_t/\Theta \tag{6}$$

$$du/d\alpha = tR_t(E_z - t)R_{tg}/\Theta \tag{7}$$

where we assume $R_{tg}=-\partial z/\partial g>0$ and thus $\Theta=-(\alpha t R_{tg}-R_g)<0$.

Equation (5) indicates an increase in public abatement by a higher fraction of the environmental tax revenue earmarked for public abatement. This result is a quite intuitive one since government sector can use more tax revenue before the policy change. Moreover under the assumption of $R_{tg}=-\partial z/\partial g>0$, pollution level declines by an increase in public abatement, which is shown by equation (6). As regard to the welfare changes, suppose that the environmental tax rate is a sufficiently small enough to establish $E_z>t$, then a higher fraction of the environmental tax revenue for public abatement can reduce pollution and hence it increases welfare. This implies that although a reduction in pollution reduces the tax revenue, which causes a negative effect on welfare, a sufficiently small value of the tax rate can ignore such a revenue loss effect. One can confirm this result by Chao and Yu (2000).

The Tariff Revenue Financed Public Abatement without the Environmental Tax Imposition

Turning to the tariff financed public abatement, totally differentiating (1), (3), (4) with $(\alpha = t = 0, d\alpha = 0)$, one can derive the changes in the endogenous variables by the same manner in the environmental tax financed public abatement case. At this point, to make clearer results in comparative statics, we impose the following assumption.

Assumption

1) *Public abatement is a substitute for the imported good production as* $R_{pg}<0$.

2) *The consumption of the imported good is a substitute for pollution as* $E_{pz}<0$[9].

From comparative statics, one obtain,

$$dg/d\beta = sM_p(1 - sE_{pu})/\Omega \tag{8}$$

$$dz/d\beta = \Pi' R_{pg}(dg/d\beta) = sM_p(1 - sE_{pu})/\Omega \tag{9}$$

$$du/d\beta = -sM_p[sE_{pz}(1 - \Pi' R_{pg}) - (E_z + R_g - E_z\Pi' R_{pg}) + sR_{pg}]/\Omega \tag{10}$$

where $\Pi' = \partial\Pi/\partial R_p > 0$ and,

$$\Omega = -\beta sE_{pu}[(E_z + R_g) - (E_z - sE_{pz})\Pi' R_{pg} - sE_{pz} - sR_{pg}] - (1 - sE_{pu})(R_g - \beta sE_{pz} - \beta sR_{pg} + \beta sE_{pz}\Pi' R_{pg})$$

Although the sign of Ω is the unknowns, however, by invoking the stability which is shown by appendix B, the sign of Ω becomes positive. At this point, one of the sufficient conditions for the stability requires $1 - sE_{pu} > 0$. Furthermore it also requires a sufficiently small fraction of the tax revenue β so that $\beta sE_{pz}\Pi' R_{pg} + R_g - \beta sE_{pz} - \beta sR_{pg} < 0$, and the first term of Ω $-\beta sE_{pu}[\cdot]$ would be negligible to ensure $\Omega > 0$.

Equation (8) indicates the changes in public abatement level by varying the exogenous policy variable. Likewise the environmental tax financed public abatement, a higher fraction of tariff revenue earmarked for public abatement can increase public abatement provision. And recalling the assumption that public abatement provision is a substitute for the imported good production as $R_{pg} < 0$, then an increase in public abatement reduces the imported good production and thereby pollution. Hence a higher fraction of tariff revenue for public abatement reduces pollution, which is expressed by equation (9).

Next, let us examine the welfare changes by equation (10). The first term of the RHS of equation (10) indicates indirect revenue effect arising by the interaction between the consumption of the imported good and pollution. Under the assumption that the consumption of the imported good is a substitute for pollution as $E_{pz} < 0$, then this term becomes positive. This is because a higher fraction of tariff revenue can reduce pollution through a reduction in the imported good production and therefore increases the consumption of the imported good. A boost of the demand for the imported good renders consumers to increase imports and so it increases tariff revenue. This revenue gain causes a positive impact on welfare.

The second term of the RHS of equation (7) captures direct public abatement effect. A higher fraction of tariff revenue for public abatement can reduce pollution through a reduction in the imported good production by $R_{pg}<0$. And suppose that $E_z+R_g>0$, then the direct public abatement effect also entails a positive impact on welfare.

The last term of the RHS of (10) indicates direct revenue effect arising by the interaction between the production of the imported good and tariff revenue. Recalling the assumption that the public abatement provision is a substitute for the imported good production, a higher public abatement level attained by an increase in the policy variable reduces the imported good production. A reduction in the imported good would also render consumers to increase imports. And if imports level boosts up, the economy can benefit from tariff revenue gain. In sum, as well as the environmental tax financed public abatement, the tariff revenue financed public abatement leads to welfare improving insofar as the noted shown above plausible assumptions prevail.

Finally, let us examine the tax revenue changes by a higher fraction of tax revenue for public abatement. To this end, let us define the each tax revenue as $G=-tR_t$, $T=sM_p$ where G is the environmental tax revenue and T is the tariff revenue. Totally differentiating those tax revenues, one find that.

$$dG/d\alpha = -tR_{tg}(dg/d\alpha) \tag{11}$$

$$dT/d\beta = sE_{pz}(dz/d\beta) - s(E_{pz} + R_{pg})(dg/d\beta) + sE_{pu}(du/d\beta) \tag{12}$$

By using the comparative statics results, the RHS of both (11) becomes negative, which implies that a higher fraction of the environmental tax revenue for public abatement reduces the environmental tax revenue itself. The intuition behind this is so straightforward that an increase in the tax revenue earmarked for public abatement reduces pollution and a reduction in pollution also reduces the environmental tax revenue $G=tz$.

On the other hand, the RHS of (12) is expected to be positive, implying that tariff revenue increases by a higher fraction of tariff revenue for public abatement. The explanations are analogous to the welfare analysis such that a reduction in pollution stimulates the consumption of the imported good as well as imports through both the direct and indirect revenue effect.

Then the following proposition summarizes the results so far.

Proposition. 1

Suppose that there is a small open economy, and the production of the imported good generates pollution. Then if the following assumption $E_z>t$ *prevails, a higher fraction of the environmental tax revenue for public abatement increases welfare through a reduction in pollution although the environmental tax revenue declines. On the other hand, suppose that* $R_{pg}<0$, $E_{pz}<0$, $E_z+R_g>0$, *and then a higher fraction of tariff revenue earmarked for public abatement raises tariff revenue and welfare through a reduction in pollution and an increase in the consumption of the imported good.*

Consider the situation that most of developing nations still heavily rely on tariffs revenue to generate domestic revenue, one might notice that the tariff revenue financed public abatement policy, which is likely to increase domestic revenue without removing a tariff, would be a potential environmental policy. Furthermore, from the point of the environmental protection, the proposition 1 indicates that even without imposing the text-type examples of the environmental policies (i.e., pollution taxes, and permits, etc), we can protect the environment. Indeed, this policy would be a potential environmental policy for the countries where the polluter pays principle does not work well. On the contrary, in case of the environmental tax financed public abatement, domestic revenue may decline by a higher fraction of the tax revenue for public abatement. However, most of nations do not heavily rely on the environmental tax revenue to sustain domestic revenue and so this case is a substantially remote from the reality. Rather, it seems reasonable to accommodate both a tariff and the environmental tax imposition simultaneously. To do so, in the next sections, we deal with the coexistence of both taxes and compare which tax revenue should be earmarked for public abatement to increase welfare and revenue effectively.

The Environmental Tax vs. The Tariff Revenue Financed Public Abatement

In this section, we introduce both taxes simultaneously and explore either the environmental tax revenue or tariff revenue should be earmarked. Firstly, we assume that only the environmental tax revenue is earmarked, $\alpha \neq 0$ while all tariff revenue is distributed to households. From the comparative statics, one can obtain,

$$dg/d\alpha|_{\beta=0} = tR_t(1-sE_{pu})/\Delta = tR_t/\Theta = tz/\Psi \tag{13}$$

$$dz/d\alpha|_{\beta=0} = -R_{tg}(dg/d\alpha) = -tR_tR_{tg}(1-sE_{pu})/\Delta = -tR_tR_{tg}/\Theta = -tzR_{tg}/\Psi \tag{14}$$

$$du/d\alpha|_{\beta=0} = tR_t[(E_z-t)R_{tg} - sE_{pz}(R_{tg}+1) - sR_{pg}]/\Delta = tz[(E_z-t)R_{tg} - sE_{pz}(R_{tg}+1) - sR_{pg}]/\Psi \tag{15}$$

where $\Delta = -(1-sE_{pu})(\alpha tR_{tg} - R_g) < 0, \Psi = (1-sE_{pu})(\alpha tR_{tg} - R_g) > 0$.

Looking at equation (13), (14), the sign of the RHS of them are the same as that of (5), (6). This is because only the environmental tax revenue is earmarked for public abatement while all tariff revenue is rebated to households. However, as regard to welfare, a higher fraction of the environmental tax revenue for public abatement affects tariff revenue and so does domestic revenue. To see this, the second term of the RHS of equation (15), $-tR_tsE_{pz}(R_{tg}+1)/\Delta>0$, captures the indirect revenue effect which causes a positive impact on welfare in such a way that the demand for the imported good rises and thereby tariff revenue by a reduction in pollution. And the third term of the RHS of equation (15), $-tR_tsR_{pg}/\Delta>0$, indicates the direct revenue effect. This effect also has a positive impact on welfare.

Overall, welfare improves by a higher fraction of the environmental tax revenue for public abatement although the economy imposes a tariff. However, the magnitude of welfare improving is higher in case of the environmental tax financed public abatement with a tariff imposition than that of without a tariff. To see this, comparing equation (15) with (7), one can easily notice that $\Theta>\Delta$ and the numerator of equation (15) is higher than that of (7). Hence, we can derive $du/d\alpha<du/d\alpha|_{s\neq0,\beta=0}$, which implies that a higher fraction of the environmental tax revenue for public abatement with a tariff imposition increases tariff revenue and welfare more than that of without a tariff imposition.

On the contrary, when only tariff revenue is earmarked for public abatement while all the environmental tax revenue is rebated to households as $\alpha=0$, $d\alpha=0$, $\beta \neq 0$, then,

$$dg/d\beta|_{\alpha=0} = sM_p(1-sE_{pu})/\Xi \tag{16}$$

$$dz/d\beta|_{\alpha=0} = -R_{tg}(dg/d\beta) = -R_{tg}sM_p(1-sE_{pu})/\Xi \tag{17}$$

$$du/d\beta|_{\alpha=0} = sM_p[(E_z - t)R_{tg} - sE_{pz}(R_{tg}+1) - sR_{pg}]/\Xi \quad (18)$$

where,

$$\Xi = -\beta sE_{pu}[(E_z - sE_{pz})R_{tg} - sE_{pz} - sR_{pg} + E_z + R_g] - (1 - sE_{pu})(R_g - \beta sE_{pz} - \beta sR_{pg} - \beta sE_{pz}R_{tg})$$

The sign of Ξ is positive by the stability.

Likewise the environmental tax financed public abatement; the results are fundamentally the same as those of independent tax imposition case, which are equation (8), (9), (10). However, since the environmental tax is imposed, the effect of the environmental tax revenue changes appears in the welfare. That is the first term of the RHS of equation (18), which is $sM_p(E_z - t)R_{tg}/\Xi$. Indeed, the sign of this term depends on the relative strength of the environmental tax rate t to the marginal damage from pollution, E_z. Suppose that a sufficiently small value of the environmental tax rate, then it guarantees a positive sign of the first term, which implies that the environmental tax revenue loss arising from pollution reduction by a higher fraction of tariff revenue for public abatement would be small enough to be ignored. Other terms of the RHS of equation (18) are the familiar terms, which indicate the direct and indirect revenue effect, both of which cause positive impact on welfare.

Finally, comparing equation (15) with (18), one can obtain the magnitude of welfare improving between the environmental tax financed and the tariff revenue financed public abatement. They are summarized in the following proposition.

Proposition 2

Suppose that there is a small open economy with an imposition of both a tariff and the environmental tax, and the production of the imported good generates pollution. And further suppose that the economy uses either tariff or the environmental tax revenue for public abatement. Then if the following assumptions $R_{pg}<0$, $E_{pz}<0$, $E_z>t$ *prevail, a higher fraction of either tax revenue for public abatement raises welfare. And the welfare effect by a higher fraction of tariff revenue for public abatement is higher than that of the environmental tax revenue for public abatement insofar as the initial value of the tax fraction rate is the same,* $\alpha=\beta>0$ *and the both initial amount of tax revenue* *is also the same,* $-tR_t=sM_p$.

Proof

Observing the denominator of both equation (15) and (18), one can easily notice that $\Psi > \Xi$. And the numerator of both equations is the same under the assumption of $-tR_t=sM_p$. Thus, we can obtain $du/d\beta|_{\alpha=0} > du/d\alpha|_{\beta=0}$.

Furthermore from the proposition 2, we can also derive the following corollary

Corollary

Suppose that $R_{pg}<0$, $E_{pz}<0$, $E_z-t>0$ *and* $-tR_t=sM_p$. *Then, the welfare effect by an introduction of a fraction of tariff revenue earmarked for public abatement is the same as that of the environmental tax revenue earmarked for public abatement.*

The proof of the corollary is also straightforward. This is because, when we assume $\alpha=\beta=0$ at initially, the denominator of both (15) and (18) becomes identical and hence we can easily derive $du/d\alpha|_{\alpha=\beta=0} = du/d\beta|_{\alpha=\beta=0}$.

The intuitive explanations of the proposition 3 are that a higher fraction of tariff revenue for public abatement has the direct and indirect revenue effect in such a way that a reduction in the imported good production and thereby pollution can raise imports, which in turn increases tariff revenue as well as public abatement fund. Nevertheless, those revenue gain effects do not contribute public abatement in case of the environmental tax revenue financed abatement since all of tariff revenue is rebated to households in the economy. Put another way, more of the taxes' revenue can be earmarked for public abatement in the tariff revenue financed abatement than in the environmental tax revenue financed one. Hence, one can expect a higher public abatement level in case of the tariff revenue financed public abatement than that of the environmental tax revenue financed public abatement. To see this, one can compare the changes in public abatement level between them, which in turn $dg/d\alpha|_{\beta=0} < dg/d\beta|_{\alpha=0}$. Moreover, a higher public abatement means a higher reduction in pollution, which is shown by (14) and (17), $|dz/d\alpha|_{\beta=0} < |dz/d\beta|_{\alpha=0}$. Indeed, the tariff revenue financed public abatement turns out to be more effective to reduce pollution and increase welfare than that of the environmental tax financed public abatement.

As regard to the corollary, if the initial fraction of both taxes' revenue for public abatement is zero, one would expect that earmarking of taxes' revenue for public abatement would be negligible. Hence, there becomes indifferent between the tariff revenue financed and the environmental tax revenue financed public abatement with respect to welfare. In this case, one can confirm $dg/d\alpha|_{\beta=0} = dg/d\beta|_{\alpha=0}$.

Turning to next, let us examine the domestic revenue changes when both a tariff and the environmental tax are imposed. Unlike the section 2 where there imposes each tax independently, now domestic revenue can be defined as $G=-tR_t+sM_p$. Totally differentiating this equation with du=0, then,

$$dG/d\alpha|_{\beta=0} = -[tR_{tg} - sE_{pz}(R_{tg}+1) - sR_{pg}](dg/d\alpha|_{\beta=0}) \tag{19}$$

$$dG/d\alpha|_{\alpha=0} = -[tR_{tg} - sE_{pz}(R_{tg}+1) - sR_{pg}](dg/d\alpha|_{\alpha=0}) \tag{20}$$

Under the assumptions of $R_{pg}<0$, $E_{pz}<0$, the second and the third terms of the RHS of (19) and (20) become positive. They indicate the familiar terms; the direct and the indirect revenue effect both of which increase domestic revenue. On the contrary, the first term of the RHS of both (19) and (20) indicates the direct revenue loss arising from a reduction in pollution and thereby the environmental tax revenue by a higher fraction of the tax revenue for public abatement. Thus the changes in domestic revenue depend on the relative strength of these effects. At this point, suppose that the environmental tax rate is a sufficiently small enough, then the RHS of both (19) and (20) becomes positive, which implies domestic revenue increasing attained by a higher fraction of the tax revenue for public abatement. Furthermore, one can compare (19) with (20) by using the following inequality as $dg/d\alpha|_{\beta=0} < dg/d\beta|_{\alpha=0}$. Then the value of the RHS of (20) is higher than that of (19) , which implies that a higher fraction of tariff revenue for public abatement would be more to increase domestic revenue than that of the environmental tax revenue. This is because the magnitude of a reduction in pollution and an increase imports as well as tariff revenue are higher in the tariff financed public abatement than that of the environmental tax financed public abatement. At this point, one should recall the fact that the direct and indirect revenue gains are absorbed for public abatement in the tariff revenue financed case while they are not in the environmental tax revenue financed case. Nevertheless, when $\alpha=\beta=0$, one can obtain, $dg/d\alpha|_{\alpha=\beta=0} = dg/d\beta|_{\alpha=\beta=0}$ and so

$dG/d\alpha|_{\alpha=\beta=0} = dG/d\beta|_{\alpha=\beta=0}$.

The Environmental Tax and The Tariff Revenue Financed Public Abatement

In the final analysis, we consider the case as which a fraction of both the environmental tax and tariff revenue is earmarked for public abatement simultaneously as $\alpha \neq 0$, $\beta \neq 0$. Then one obtain the followings.

$$dg/d\alpha = -tR_t(1-sE_{pu})/\Phi \quad (21)$$

$$dg/d\beta = sM_p(1-sE_{pu})/\Phi \quad (22)$$

$$dz/d\alpha = -R_{tg}(dg/d\alpha) = tR_tR_{tg}(1-sE_{pu})/\Phi \quad (23)$$

$$dz/d\beta = -R_{tg}(dg/d\beta) = -R_{tg}sM_p(1-sE_{pu})/\Phi \quad (24)$$

$$du/d\alpha = -tR_t[(E_z - t)R_{tg} - sE_{pz}(R_{tg}+1) - sR_{pg} + (E_z + R_g)]/\Phi \quad (25)$$

$$du/d\beta = sM_p[(E_z - t)R_{tg} - sE_{pz}(R_{tg}+1) - sR_{pg} + (E_z + R_g)]/\Phi \quad (26)$$

where $\Phi = -\beta sE_{pu}[(E_z - t)R_{tg} - sE_{pz}(R_{tg}+1) - sR_{pg} + (E_z + R_g)]$

$-(1-sE_{pu})(R_g - \beta sE_{pz} - \beta sR_{pg} - \beta sE_{pz}R_{tg} - \alpha tR_{tg})$

Note that the sign of Φ becomes positive by the stability.
Observing the RHS of both (25) and (26), one can obtain the following proposition.

Proposition. 3

Suppose that there is a small open economy with an imposition of both a tariff and the environmental tax, and the production of the imported good generates pollution. And further suppose that the economy uses both tariff and the environmental tax revenue for public abatement at simultaneously. Then if the following assumptions $R_{pg}<0$, $E_{pz}<0$, $E_z-t>0$ *prevail, the welfare effect by a higher fraction of tariff revenue or the environmental tax revenue for public abatement becomes positive and its effect is the* *same regardless of which tax revenue is earmarked for public abatement insofar as the initial amount of the tax revenue is the same between a tariff and the environmental tax,* $-tR_t=sM_p$.

Unlike the previous section where either the tax revenue is earmarked for public abatement, both the direct and the indirect revenue effects are absorbed for public abatement even in the environmental tax financed public abatement case. This is because, besides the environmental tax revenue, a part of tariff revenue is earmarked for public abatement and so a higher fraction of the environmental tax revenue for public abatement affects the tariff revenue which is earmarked for public abatement. The opposite case also holds true as which a higher fraction of tariff revenue affects the environmental tax revenue which is earmarked for public abatement.

Finally, comparing (18) with (26), we can obtain the following proposition.

Proposition 4..

The welfare effect of the tariff revenue financed public abatement without the environ-mental tax revenue finance is higher than that with the environmental tax revenue finance.

The proof is so straightforward that one must notice $\Phi>\Xi$ and thus one obtain $du/d\beta|_{\alpha=0} > du/d\beta|_{\alpha\neq0}$ since the numerator of both equations are identical.

Intuitively, the environmental tax revenue loss arising from a higher fraction of tariff revenue for public abatement dampens pollution reduction and thereby welfare. Hence, the magnitude of the welfare effect by a higher fraction of the tariff revenue for public abatement attached with the environmental tax financed public abatement becomes lower. Indeed, the proposition 4 implies that all of the environmental tax revenue should be rebated to households rather than earmarked for public abatement.

Ⅳ. Concluding Remarks

So far, we have demonstrated the tax revenue financed public abatement policy in a general equilibrium framework. Recalling the bottleneck for the environmental protection such that tariffs protection generates both domestic revenue and pollution, the tariff revenue financed public abatement policy turns out to be a remedy of this bottleneck since it can reduce pollution and increase tariff revenue without removing a tariff. This result is very meaningful for the certain developing nations, which suffer from the environmental pollution arising from tariffs protection, to pursue environmental policies to increase welfare. At this point, the fact, which tariffs revenue plays a dominant role to generate domestic revenue in most of developing nations and the polluter pays principle does not work well, can strengthen the effectiveness of the tariff revenue financed public abatement.

Besides paying attention to a tariff, this paper addressed the environmental tax financed public abatement policy so as to compare the tariff revenue financed public abatement. Especially, we derived the condition that using only tariff revenue financed for public abatement is better than using both taxes' revenue financed public abatement to increase domestic revenue and welfare. This result can illuminate the fiscal matters as to how and which tax revenue should be earmarked for public abatement to enhance domestic revenue and welfare effectively.

With these results in mind, one can explore other taxes' revenue financed public abatement policies for the environmental protection. For instance, one can incorporate the consumption tax and/or the income tax into the framework of this paper. However, in case of the consumption tax, which is one of the primary taxes in industrialized nations, the results are fundamentally the same as the tariff financed public abatement since tariff contains the production subsidy and the consumption tax.

Furthermore, from the point of foreign direct investment and the environment, introducing an internationally mobile capital into this framework can enhance the realities and therefore it can elaborate the tax revenue financed public abatement. Moreover, we have assumed that the environmental pollution is generated from the certain production activity throughout this paper; however we can relax this assumption so as to include the consumption-based pollution. Those elaborations would hopefully become a meaningful future research.

Appendix A

1. Derivation for equation (5), (6), (7) and (13), (14), (15).

Totally differentiating equation (1)',

$$dz = -R_{tg}dg \tag{A.1}$$

Then if we allow an imposition of a tariff on the imported good and all of tariff revenue is rebated to households,, then we have $s \neq 0, \beta = 0$. With this in mind, totally differentiating equation (3) and (4),

$$(\alpha t R_{tg} - R_g)dg = -tR_t d\alpha \tag{A.2}$$

$$(1 - sE_{pu})du + (E_z - sE_{pz})dz - [(E_z + R_g) - tR_{tg} - sE_{pz} - sR_{pg}]dg = 0 \tag{A.3}$$

Substituting (A.1) into (A.2) and (A.3), one can obtain,

$$\begin{bmatrix} 0 & (\alpha t R_{tg} - R_g) \\ (1 - sE_{pu}) & -[(E_z + R_g) - tR_{tg} - sE_{pz} - sR_{pg} + (E_z - sE_{pz})R_{tg}] \end{bmatrix} \begin{bmatrix} du \\ dg \end{bmatrix} = \begin{bmatrix} -tR_t \\ 0 \end{bmatrix} d\alpha$$

The determinant of the matrix is Δ, where $\Delta = -(1 - sE_{pu})(\alpha t R_{tg} - R_g) < 0$. By using this matrix, one can easily obtain (13), (14), (15).

On the other hand, one can also derive (5), (6), (7) by permitting $s=0$ in the above matrix.

2. Derivation for equation (8), (9), (10). ($\alpha = t = 0$, $d\alpha = 0$)

Totally differentiating (3), (4), then one can yield the followings

$$\beta sE_{pu}du + \beta sE_{pz}dz - (\beta sE_{pz} + \beta sR_{pg} - R_g)dg = -sM_p d\beta \tag{A.4}$$

$$(1 - sE_{pu})du + (E_z - sE_{pz})dz - [(E_z + R_g) - sE_{pz} - sR_{pg}]dg = 0 \tag{A.5}$$

Note that, to derive both (A.4) and (A.5), we used the following relationships as $M_{pz} = E_{pz}$, $M_{pg} = -E_{pz} - R_{pg}$, $M_{pu} = E_{pu}$ since we know $M_p(p, z, g, t, u) = E_p(p, z-g, u) - R_p(p, g, t) > 0$. Finally, totally differentiating (1), then

$$dz = \Pi' R_{pg}dg \tag{A.6}$$

Substituting (A.6) into (A.4) and (A.5), one can have the following matrix.

$$\begin{bmatrix} \beta sE_{pu} & (R_g - \beta sE_{pz} - \beta sR_{pg} + \beta s\Pi' R_{pg}) \\ (1 - sE_{pu}) & -[(E_z + R_g) - (E_z - sE_{pz})\Pi' R_{pg} - sE_{pz} - sR_{pg}] \end{bmatrix} \begin{bmatrix} du \\ dg \end{bmatrix} = \begin{bmatrix} -sM_p \\ 0 \end{bmatrix} d\beta$$

One can solve these equations and obtain (8), (9), (10).

Note that,

$$\Omega = -\beta sE_{pu}[(E_z + R_g) - (E_z - sE_{pz})\Pi' R_{pg} - sE_{pz} - sR_{pg}] - (1 - s' E_{pu})(R_g - \beta s' E_{pz} - \beta s' R_{pg} + \beta s' E_{pz}\Pi' R_{pg})$$

where the value of the determinant of the above matrix is Ω. Although the sign of Ω is the unknowns, the stability attached by appendix B establishes $\Omega > 0$.

3. Derivation for (16)-(18) ($\alpha = t = 0$, $d\alpha = 0$)

By totally differentiating (3), one can yield the following

$$\beta sE_{pu} du + \beta sE_{pz} dz - (\beta sE_{pz} + \beta sR_{pg} - R_g - \alpha tR_{tg}) dg = tR_t d\alpha - sM_p d\beta \tag{A.7}$$

Totally differentiate (1) yields the followings,

$$dz = -R_{tg} dg \tag{A.8}$$

And differentiating (4), then one must have,

$$(1 - sE_{pu}) du + (E_z - sE_{pz}) dz - [(E_z + R_g) - tR_{tg} - sE_{pz} - sR_{pg}] dg = 0 \tag{A.9}$$

Substituting (A.8) into (A.7) and (A.9), then one can have the following matrix.

$$\begin{bmatrix} \beta sE_{pu} & (R_g - \beta sE_{pz} - \beta sR_{pg} - \beta sE_{pz}R_{tg}) \\ (1 - sE_{pu}) & -[(E_z - t)R_{tg} - sE_{pz}(R_{tg} + 1) - sR_{pg} + (E_z + R_g)] \end{bmatrix} \begin{bmatrix} du \\ dg \end{bmatrix} = \begin{bmatrix} tR_t \\ 0 \end{bmatrix} d\alpha + \begin{bmatrix} -sM_p \\ 0 \end{bmatrix} d\beta$$

Then one can obtain (16), (17), (18).

$$\Xi = -\beta sE_{pu}[(E_z - t)R_{tg} - sE_{pz}(R_{tg} + 1) - sR_{pg} + (E_z + R_g)]$$

$$-(1 - sE_{pu})(R_g - \beta sE_{pz} - \beta sR_{pg} - \beta sE_{pz}R_{tg}),$$

where the value of the determinant of the above matrix is Ξ. Likewise the sign of Ω, the sign of Ξ becomes positive by the stability.

4. Derivation for (21)-(26) ($\alpha \neq 0$, $t \neq 0$, $\beta \neq 0$, $s \neq 0$)

Totally differentiating (1)', (3), (4) with $\alpha \neq 0$, $t \neq 0$, $\beta \neq 0$, $s \neq 0$,

$$\begin{bmatrix} \beta sE_{pu} & (R_g - \beta sE_{pz} - \beta sR_{pg} - \beta sE_{pz}R_{tg} - \alpha tR_{tg}) \\ (1 - sE_{pu}) & -[(E_z - t)R_{tg} - sE_{pz}(R_{tg} + 1) - sR_{pg} + (E_z + R_g)] \end{bmatrix} \begin{bmatrix} du \\ dg \end{bmatrix} = \begin{bmatrix} tR_t \\ 0 \end{bmatrix} d\alpha + \begin{bmatrix} -sM_p \\ 0 \end{bmatrix} d\beta$$

$$\Phi = -\beta sE_{pu}[(E_z - t)R_{tg} - sE_{pz}(R_{tg} + 1) - sR_{pg} + (E_z + R_g)]$$

$-(1-sE_{pu})(R_g - \beta sE_{pz} - \beta sR_{pg} - \beta sE_{pz}R_{tg} - \alpha tR_{tg})$ and the sign of is also positive by the stability.

Appendix B

Since the sign of is the unknowns, we assume the following stability condition presented by Abe (1992).

$$\dot{g} = \beta sM_p(p, z, g, u) - gC^g(w) \qquad \text{(B.1)}$$

If equilibrium is a locally stable one, we can establish $d\dot{g}/dg < 0$. To calculate $d\dot{g}/dg < 0$, we use (A.4), (A.5), (A.6),

$$\frac{d\dot{g}}{dg} = \beta sE_{pu}\left(\frac{du}{d\alpha}\right) + [R_g - \beta sE_{pz} - \beta sR_{pg} + \beta sE_{pz}\Pi' R_{pg}] < 0 \qquad \text{(B.1)'}$$

From (A.4) and (A.5), we easily obtain

$$\frac{du}{dg} = \frac{[(E_z + R_g) - (E_z - sE_{pz})\Pi' R_{pg} - sE_{pz} - sR_{pg}]}{(1 - sE_{pu})} \qquad \text{(B.2)}$$

By substituting (B.2) into (B.1)', we can derive

$$\frac{d\dot{g}}{dg} = -\frac{\Omega}{(1 - sE_{pu})} < 0$$

The sufficient conditions to guarantee the stability are $1 - sE_{pu} > 0$ and $\Omega > 0$.

Notes

1. See Turner et al. (1994).
2. See Todaro (1996), indiacating that in open economies with up to 40% of GDP derived from foreign trade, an average import duty of 25% will yield a tax revenue equivalent to 10% of GNP. It implies that

they can procure the large source of public revenues from import and export duties and sometimes they become an efficient substitute for the corporate income tax in developing countries.

3. As regard to the tax revenue financed issues in general equilibrium framework other than Abe (1992), Michael and Hatzipanayotou (2001) incorporated international migration into the tax revenue financed public good provision context to examine migration effect with respect to welfare. In another aspect of the tax revenue financed issues, Hatzipanayotou and Michael (2000) addressed the tax financed foreign aid analyzed which tax revenue should be used for foreign aid.
4. Relevant to domestic revenue issues, the double dividend issues arisen by imposing the environmental policies are demonstrated by Bovenberg and de Mooji (1994), Pary (1994), Pearce (1991).
5. Note that $v = v^p + v^g$ from equation (1) and we know $gC^g(w)$ can be defined as the total cost of public abatement, where $w=\tilde{R}_{vp}(p, v^p)$. By substituting $v^g=gC^g(w)$ into (1) yields $v=v^p+gC^g(\tilde{R}_{vp}(p, v^p))$ and we can write $v^p=v^p(p, g)$. Thus we obtain $R(p, g)=\tilde{R}(p, v^p(p, g))$. See Abe (1992) for the detailed discussions.
6. See Chao and Yu (1999).
7. In this paper, we normalize $E_u=1$.
8. As regard to the tax reform issues, see Copeland (1994), Beghin at el. (1997).
9. Copeland (1994) provided an example of $E_{pz}<0$ as which pollution destroys wildness areas and so the demand for the imported good just like hiking boots declines.

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